

New Agri-Silvo-Pastoral Model Utilizing Terrace Riser Enhancing Crop and Livestock Production Developed in Nepal

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Abstract: Twelve fodder species with maize (*Zea mays*) and millet (*Eleusine coracana*) were evaluated under agri-silvo-pastoral system along the Terrace risers (T-risers) of cropping land in the Agricultural Research Station Pakhribas, Nepal. Major aim of innovative agroforestry experiment designed and tested first time in Nepal was to utilize one-third land in risers of cropping terraces due to limited lands of smallholders to produce green fodders needed for livestock. Trees were planted at 1.5 m on the terrace edges and ground fodders at 30-50 cm on the risers. Trees were not allowed to grow tall to avoid shade effect on crops grown in terraces. They were felled at breast height in second year growing coppices for fodder. The results showed higher survival (76% to 100%), growth (1-3 m high) and yield of improved forages and fodder trees indicating potential for cultivation on T-risers. Dry matter (DM) of tree fodders varied 31%-49%, and ground fodders 19%-32%. DM yields ranged 3.0 t/ha (*Stylosanthes guanensis*) to 26.5 t/ha (*Pennisetum purpureum*). Combined effects of fodder species on major hill crops, maize and finger millet growth, yield and other attributes were monitored in the terraces. Most mean data were significant and at par between the treatments. Better combinations of tree and ground fodders for higher grain and stover yields (3.1 t/ha and 3.4 t/ha, respectively) of maize were *Grewia optiva/Thysalonaema maxima*, *Desmodium intortum*, *Ficus auriculata/Setaria anceps*, *D. intortum* (2.7 t/ha and 3.3 t/ha, respectively). Promising combinations for finger millet growth and yields (2-3 t/ha) were *G. optiva/T. maxima*, *Bauhinia purpurea/S. anceps*, *F. semicordata/P. cetaceum*. Soil analysis result showed positive impact of fodders on the risers where organic matter was highly increased after three years. Farmers and stakeholders also evaluated this technology that has been successful and recommended for similar ecological regions.

Key words: Terrace riser, fodder trees, forage species, maize and millet, agri-silvo-pastoral system, new model.

1. Introduction

The 1st World Congress of Agroforestry held in 2004 at Orlando, USA, declared that “Agroforestry is now a science without borders, can tackle problems of biodiversity, rural poverty, deforestation, land degradation, genetic erosion, soil fertility decline, climate change, environment, food and nutritional security” [1]. It is obvious that “Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence”

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[2]. National workshop organized by Nepal’s Ministries of Agriculture Development and Forest and Soil Conservation in collaboration with the World Agroforestry Center (ICRAF) formulated Kathmandu Declaration along with response plan to develop a National Agroforestry Policy for Nepal. It would review and execute various recommendations in agroforestry including this new Terrace riser (T-riser) farming agri-silvo-pastoral model [3].

Trees form an integral part of the hill agriculture system for the Nepalese peasants [4]. They provide fodder and bedding for farm animals, wood for cooking, fencing and other purposes to meet the daily need of the rural households. Therefore, trees and fodders/forages are important resources for the farming communities, particularly in the hills of Nepal [5].

Fodders are lopped from the trees mainly in dry period of the year as Traditional agroforestry system has been supporting to fulfill the household needs [6]. It helps sustain farm, prevent land degradation and improve soil and environment to some extent. However, over exploitation of the forests and handing over it to the communities has led to farmers becoming more dependent on trees of private land. It is reported [7] that farmers' response to the declining forest situation and growing more trees on farmland causes adverse effect on crops [8]. Broad leaved, tall and big crowned trees have severe effect on the field crops. The majority of peasants have small holdings of terrace lands (< 0.7 ha) which have risers of different height. Need of tree fodders, ground forage grasses and fire-wood from the farmland has been increasing with the ever-increasing population [9, 10]. However, growing more trees is a constraint in the same cropping land. Researchers [4, 10] have highlighted the scope of agroforestry for the hill farming communities. But limited land for growing crops and shade effect of trees has compelled to seek alternative to overcome the problems.

Relevant literatures pertaining on the new model of agroforestry is scanty. However, general literatures suggest that effect of trees on crop growth and yield varies with tree species, their size, distance from tree and crop species. According to the authors [7, 9, 11] shading, water dripping, root disturbance, competition for nutrient, light and moisture are the negative impact of tree-crop interface, which the local people also experienced [5]. It is believed that leguminous trees such as *Leucaena* sp., *Albizia* sp., *Acacia* sp., *Bauhinia* sp. etc. have a positive influence on adjacent crop. Farmers in the hills prefer fodder trees based on livestock and soil [10]. They like nutritious fodders for livestock and categorize them as Posilo (nutritious) and also, they prefer fodders impacting positively soil and crop, and mention them as Malilo (fertile). The species negatively affecting the soil and crops is called Rukho (unfertile). As farmers are interested in fodder

trees and forage crops characterizing Posilo and Malilo, selection of fodder species rich in nutrients, nitrogen fixing, soil conserving, high fodder yielding, having less shading effect on crops etc. should be given priority [6, 12]. Effects of *Eucalyptus camaldulensis* on the yield and yield components of adjacent crop *Zea mays* and *Panicum miliaceum* showed a reduction from tree stand. Plant biomass, height, stand and grain yield of both crops decreased with distance to eucalypts [13]. Maize grain and biomass yields reduction were 6.6 to 15 fold difference respectively from tree stand to 20 m (control). Finger millet grain yield difference was around 2.9 fold from tree stand. Poor performance of crops was competition for growth resources between eucalypts and adjacent crops.

1.1 Need of Testing Fodders on Terrace Risers and Development of a New Agro-Technology

Numbers of reasons behind testing the hypothesis of fodder cultivation (trees/shrubs and grass/forage species) on T-risers of cropping land were identified as below:

- Majority of peasants have small holdings and use the land to grow different crops in summer and winter seasons. Fodders are generally not grown due to limited land.
- Land in the hills is composed of terrace and riser. A measurement estimated that on an average two-third land is occupied by terraces and one-third is occupied by risers. Risers are left barren and unutilized, so hypothesis of fodder cultivation should be explored.
- Almost all households keep livestock, either cattle or buffalo or both and also farm goat/sheep. Dairy milk collection and sale has been expanded in the villages.
- Crops and animals are interdependent with regards to food, feed and fertilizer. So, farmers have mixed and complex farm, which need to be sustained. They have to meet daily need of fodder for livestock, leaf litter for manure and fuel-wood for cooking.

- Lack of fodder is crucial. Nutritious fodder is scarce for dairy animals. Increasing fodder production and supply during lean period from September to May is essential.

- Poor farmers are not able to afford costly chemical fertilizers for crops. They need to produce livestock manure to apply in the soil. Organic farming is also gaining popularity in Nepal.

- It is difficult to find nutritious fodder in the forest. Fodder collection takes more time and it has been drudgery to women and children.

- Soil erosion and landslide in the farmlands in hills is a severe problem. Conserving soil and land and improving farm environment is becoming a very necessary action.

Rapid progress in modeling of tree and crop performance is on-going. It may fulfill the potentiality of agroforestry that contribute to improve food security, reduce land degradation, mitigate climate change, and increase sustainability [14]. In the parklands' farming systems, annual crops are grown under scattered trees whose pruning was done to modify the crown and root distribution pattern improving light and air availability. Contribution of each component was considered for resource use efficiency and low shade effects on cultivated plants with high fertility around trees [15].

1.2 Objectives of the Research

The main objective of proposed research was to explore feasibility of grass and forage crops cultivation in the unutilized 1/3 land of T-riser. Associated purposes were to test/evaluate survival and growth performance of selected fodder trees and forage species, reveal the hypothesized possibility of cultivation on the T-riser, and to quantify effects of fodder tree/forage species on crops and identify suitable combination of tree and ground fodders in T-riser for maize and finger millet. The overall hypothesis was to plant closely greater number of trees for increased fodder production, not allowing

them to grow tall and hence minimizing shade effect on the crops grown in the terrace.

1.3 Terrace-Riser Based Agroforestry: A New Design

T-riser-based agroforestry is an innovative agro-technology design/model having different characteristics because fodder is cultivated in the risers of cropped terraces. Risers of different height exist in the cropping lands. A measurement ranged 0.5 m to 3 m, average height being 1.3 m. The land occupied by the riser was 20% to 50%, where average was 33% of the terrace area.

Conventionally, only the naturally grown grasses and few trees are found in the risers of cropping terrace land. These are not evenly distributed and may dry and die during off-rain period of 6-8 months. Few non-nutritious, non-palatable species of *Ipomoea*, *Digiteria*, *Sacharam*, and others are harvested and fed to farm animals during monsoon period. Therefore, growing improved forages in the risers and harvesting them in rotation to feed the livestock round the year seems rationale. Lack of separate land for growing fodders compelled the farmers to plant fodder trees having low shade effect for the crops.

The main author of this paper had experience of cultivating medicinal herb chiretta (*Swertia chirayita*) on the T-risers in Dhankuta and other districts. The land was successfully utilized through riser farming.

In this new design of agroforestry, it was believed that shade effect of trees would be minimized if they are cut at breast height in the second-third year and the regenerated coppices would be fodders for succeeding years. So the trees were not allowed to grow taller. Spacing was closer to adjust a greater number of trees for more fodders. The design was favorable as expected: the ground forages grew well in the riser. There was limited shade effect on the growing crops in the terraces as compared to conventional practice.

2. Materials and Methods

2.1 Experimental Site and Design

Experimental plots were established, and agroforestry research conducted in the hill Agricultural Research Station (ARS) Pakhribas and outreach sites, Eastern Nepal. On-farm verification trials were conducted in Dhankuta, Ilam and Terhathum districts. The research sites (15) were located at different elevations (1,100-2,100 m above mean sea level (amsl)). This paper has been prepared from the five years on-farm field experiment data of Dhankuta municipality-3, Patle village located at 1,400 m amsl in the land of peasant Narayan Bhandari.

The experiment was laid out in split-plot design where fodder species were in main plots and maize (*Zea mays*) and relayed millet (*Eleusine coracana*) were planted in sub-plots annually. Six ground fodder species were transplanted under six fodder tree species. The treatments were completely randomized in the three replications (three terraces and their risers as replicates). Plot size was 6 m long and 2 m high in the risers. In the terraces, 6 m × 2.5 m sized treatment plots were laid out, both in the edge and bottom part of the risers for observation of crops. Fodder trees were planted along the edge of terrace in one row at 1.5 m in the first year. Spacing for grass/forage species was provided based on species: vigorously growing/tiller forming species *Pennisetum purpureum*, *Thysalonaema*

maxima and *P. cetaceum* planted at 50 cm × 50 cm and other three species planted at 50 cm × 30 cm.

2.2 Experimented Fodder Species and Selection Criteria

Three dozen of locally adapted tree fodders and grass/forage species were identified as promising in the hills and mountain. Those were collected and raised in the station nursery as germplasm. The species were selected considering the farmers' preferences/criteria and need assessment: fast growing, nutritive, palatable to livestock, high yielding, possibility to harvest more than twice a year, drought tolerant, leguminous/nitrogen fixing, suitable for 1,000-2,000 m amsl, perennial, soil conserving, etc. The fodder species possessing above 6-9 criteria were further selected for testing in the T-riser of the proposed field experiment. All fodder tree species (Table 1) were indigenous and locals (*B. purpurea*, *F. auriculata*, *F. nemarolis*, *F. semicordata* var. *montana* Amatya, *Grewia optiva* and *Litsea monopetala*). Forage species (Table 1) were both indigenous (*P. cetaceum* and *T. maxima*) and exotic (*D. intortum*, *P. purpureum*, *S. anceps*, *S. guanensis*). Some researchers [16] noted that farmers select tree species based on output and crop species based on input. Fast growing, multipurpose, and less competitiveness in intercropping were the most preferred species. The list of experimental fodder species is presented with scientific, English and local names in Table 1.

Table 1 Trees and ground fodder species planted in the experiment.

Scientific name	English name	Nepalese/local name
<i>Bauhinia purpurea</i>	NA	Tanki
<i>Ficus auriculata</i>	NA	Nebaro
<i>F. nemarolis</i>	NA	Dudhilo
<i>F. semicordata</i> var. <i>montana</i> Amatya	NA	Raikhanyu
<i>Grewia optiva</i>	NA	Bhimal/Ghotli
<i>Litsea monopetala</i>	NA	Patmero/Kutmero
<i>Desmodium intortum</i>	Desmodium	Desmodium
<i>Pennisetum purpureum</i>	Napier	Napier
<i>P. cetaceum</i>	NA	Dhus
<i>Setaria anceps</i>	Setaria	Setaria
<i>Stylosanthes guanensis</i>	Stylo	Stylo
<i>Thysalonaema maxima</i>	Broom grass/Tiger grass	Amriso/Amliso

The most commonly grown crops in vast cultivable area maize (*Zea mays*) and finger millet (*Eleusine coracana*) were planted annually in the terraces.

3. Results and Discussion

3.1 Fodder Tree Species Observation Data

Survival of the fodder trees was 92% to 100% (Table 2), except *L. monopetala* (83%). Field visitors evaluated it as highly successful. One-year old seedlings/saplings transplanted in the T-riser were fully established in the second year attaining 1.5-2.5 m high which were felled at breast height and fresh fodder of coppices harvested every year. Dry matter (DM) of fodders was analyzed in the station lab where small twigs had higher DM than foliages. The average DM (Table 2) ranged 20%-44% which was within the reference result but the data were non-significant. The mean DM did not vary sharply among the fodder trees. However, *F. semicordata* produced the highest (33%) DM and yield (2,246 kg/ha) followed by *G. optiva* (1,040 kg/ha). Vigorously growing and high yielding *F. semicordata* was lopped twice a year [8]. *B. purpurea* and *F. nemoralis* produced least fodder and DM yield (210-240 kg/ha) due to slow growth and low DM percent. Plant heights were measured annually but the data are not presented. Average tree height was 2-3 m in the second year and 3-4 m in the third-fourth year. Coppice height reached up to 3.5 m (*F. semicordata*). It was reported that fodder biomass was increased with tree age based on spacing: 7.29 t/ha under 4 m, 5.256 t/ha on 6 m and 3.84 t/ha on 2 m [17].

3.2 Forage Species Observation Data

Survival and DM of ground fodder/forage species are presented in Table 3. Survival of all species was encouraging (85%-98%) in the T-risers. *P. purpureum*, *D. intortum* and *S. anceps* survived 98%-96%, higher than general. The DM varied 12%-14% (*S. anceps*, *P. cetaceum*) to 34%-37% (*T. maxima*, *P. cetaceum*, *S. guanensis*). It was the highest (30.1%) in *T. maxima*. Rainy period harvested fodders contained lower DM than the dry period, however variation was based on species, combination

with trees, and growth behavior. The DM and forage yields were significant ($p < 0.05$) and at par. Based on the annual fodder production *S. guanensis*, *S. anceps* and *D. intortum* were low yielders (3-5 t/ha) and remaining three species were found with high yielding (14-25 t/ha) (Table 3). Fast growing species such as *P. purpureum* and *S. anceps* were harvested 2-3 times a year. It was reported [18] that effect of oak tree canopy was found positive on pasture forages, 19% higher yields obtained beneath the canopy than on open grassland as tree effects.

3.3 Maize Crop Observation Data

Yields and other major agronomic traits of maize (*Zea mays*) were monitored year-wise in the experiment. The results are presented below. Analysis of variance (ANOVA) of the generated mean data were shown to be highly significant ($p < 0.01$), to non-significant between the treatments.

The first year's results (Table 4) showed that significantly ($p < 0.05$) better fodder trees were *G. optiva* and *F. auriculata* combinations which favored to produce more grain yields of maize (2,699-2,960 kg/ha). They had higher plant heights (214-224 cm), stands (25.6-31.7 thousand (ths)/ha) and cob numbers (27.2-28.3 ths/ha) as compared to other combination. Better tree/forage for grain yields found *F. semicordata/T. maxima* (3,381 kg/ha), *F. auriculata/S. anceps* (3,330 kg/ha) and *G. optiva/T. maxima* (3,250 kg/ha) which produced significantly higher yield than control (2,590 kg/ha). Air dried stover yield of *F. auriculata* combination was superior (2,500 kg/ha) to other treatments, but was inferior to the control (3,214 kg/ha). The season was not favorable for maize as there was certain drought period during early growth stage. Table 5 presents the yield and agronomic traits of maize monitored in the second year. The data showed statistically significant ($p < 0.05$) results between the means of grain and stover yields, height and stands. *G. optiva* (3,166 kg/ha) and *B. purpurea* (2,913 kg/ha) enhanced more grain yields. Under

Table 2 Survival, dry matter (DM) and DM yields of tree fodder in terrace edges.

Fodder tree species	Survival (%)	DM range (%)	DM mean (%)	DM yield (kg/ha)
<i>B. purpurea</i>	100	22-38	29	210
<i>F. auriculata</i>	92	23-35	30	650
<i>F. nemarolis</i>	94	20-32	26	240
<i>F. semicordata</i>	92	24-42	33	2,246
<i>G. optiva</i>	100	22-44	28	1,040
<i>L. monopetala</i>	83	24-36	31	812

Table 3 Survival, DM and DM yields of fodder/forages in Terrace risers.

Ground fodder species	Survival (%)	DM range (%)	DM mean (%)	DM yield (t/ha)
<i>D. intortum</i>	96	20-30	23.2	4.10
<i>P. purpureum</i>	98	14-26	18.5	25.52
<i>P. cetaceum</i>	87	17-36	22.0	21.24
<i>S. anceps</i>	96	12-25	18.4	5.02
<i>S. guanensis</i>	85	22-34	28.2	3.40
<i>T. maxima</i>	88	21-37	30.1	14.54

Table 4 Effect of different combinations of riser planted tree and forage species on yield and other traits of maize (year 1), Dhankuta district, Patle.

Treatment combination	Grain yield (kg/ha)	Stover yield (kg/ha)	Plant stand (ths/ha)	Barren plants (ths/ha)	No. of cobs (ths/ha)	Ear height (cm)	Plant height (cm)
<i>F. auriculata/S. anceps</i>	3,330	3,003	35.0	3.3	31.7	102	191
<i>F. auriculata/S. guanensis</i>	2,366	2,166	31.7	3.3	23.3	105	233
<i>F. auriculata/D. intortum</i>	2,400	2,333	28.3	1.7	30.0	108	217
<i>B. purpurea/P. cetaceum</i>	2,158	2,106	20.0	1.7	18.3	118	232
<i>B. purpurea/S. anceps</i>	2,025	2,250	20.8	0.0	23.3	115	210
<i>B. purpurea/S. guanensis</i>	1,833	2,166	20.0	0.0	217	109	198
<i>F. semicordata/T. maxima</i>	3,381	3,333	36.7	0.0	33.3	115	217
<i>F. semicordata/P. cetaceum</i>	2,333	2,000	20.0	0.0	23.3	76	199
<i>F. semicordata/P. purpureum</i>	1,850	1,750	18.3	0.0	16.7	98	178
<i>G. optiva/T. maxima</i>	3,250	3,166	28.3	1.7	26.7	132	245
<i>G. optiva/P. cetaceum</i>	2,103	1,666	20.3	0.0	20.0	99	202
<i>G. optiva/D. intortum</i>	3,528	2,000	28.3	0.0	35.0	124	226
<i>L. monopetala/P. purpureum</i>	1,980	1,500	21.7	5.0	18.3	80	169
<i>L. monopetala/T. maxima</i>	2,433	2,166	36.7	0.0	26.7	115	217
<i>L. monopetala/S. guanensis</i>	1,550	1,666	18.3	6.0	18.0	63	127
<i>F. nemarolis/P. purpureum</i>	1,598	1,500	18.3	0.0	16.7	107	178
<i>F. nemarolis/D. intortum</i>	2,850	2,333	28.3	0.0	28.3	112	217
<i>F. nemarolis/S. anceps</i>	1,916	2,166	21.7	3.3	18.3	72	171
Control/Open	2,590	3,214	25.5	0.6	30.2	98	172

Ths = thousand.

Table 5 Effect of different combinations of riser planted tree and forage species on yield and other traits of maize (year 2), Dhankuta district, Patle.

Treatment combination	Grain yield (kg/ha)	Stover yield (kg/ha)	Plant stand (ths/ha)	Barren plants (ths/ha)	No. of cob (ths/ha)	Ear height (cm)	Plant height (cm)
<i>F. auriculata/S. anceps</i>	2,865	4,226	45.8	0.0	62.2	109	208
<i>F. auriculata/S. guanensis</i>	2,601	5,256	41.6	0.0	43.3	135	237
<i>F. auriculata/D. intortum</i>	2,238	5,396	32.7	3.3	48.3	108	186
<i>B. purpurea/P. cetaceum</i>	2,715	3,581	31.5	0.0	58.0	120	225

(Table 5 to be continued)

Treatment combination	Grain yield (kg/ha)	Stover yield (kg/ha)	Plant stand (ths/ha)	Barren plants (ths/ha)	No. of cob (ths/ha)	Ear height (cm)	Plant height (cm)
<i>B. purpurea</i> / <i>S. anceps</i>	3,105	4,678	40.1	1.6	55.0	123	227
<i>B. purpurea</i> / <i>S. guanensis</i>	2,920	4,702	32.9	0.0	48.3	117	227
<i>F. semicordata</i> / <i>T. maxima</i>	1,803	3,675	29.9	1.6	52.8	125	235
<i>F. semicordata</i> / <i>P. cetaceum</i>	2,173	2,929	39.4	0.0	53.3	103	200
<i>F. semicordata</i> / <i>P. purpureum</i>	2,141	3,928	32.1	1.6	43.3	124	234
<i>G. optiva</i> / <i>T. maxima</i>	3,451	5,428	41.1	1.6	50.0	114	244
<i>G. optiva</i> / <i>P. cetaceum</i>	3,225	5,055	41.7	0.0	55.0	123	231
<i>G. optiva</i> / <i>D. intortum</i>	2,822	3,650	32.5	1.6	50.0	124	237
<i>L. monopetala</i> / <i>P. purpureum</i>	1,890	4,240	30.1	1.6	33.3	117	220
<i>L. monopetala</i> / <i>T. maxima</i>	3,956	5,666	43.8	3.3	60.0	134	236
<i>L. monopetala</i> / <i>S. guanensis</i>	1,839	4,444	36.7	1.6	53.8	105	206
<i>F. nemarolis</i> / <i>P. purpureum</i>	1,839	3,456	40.7	0.0	59.2	69	156
<i>F. nemarolis</i> / <i>D. intortum</i>	2,507	2,757	35.0	1.6	53.3	114	224
<i>F. nemarolis</i> / <i>S. anceps</i>	2,419	5,395	41.7	3.3	60.0	93	192
Control/Open	3,877	4,999	40.0	0.0	60.5	110	229

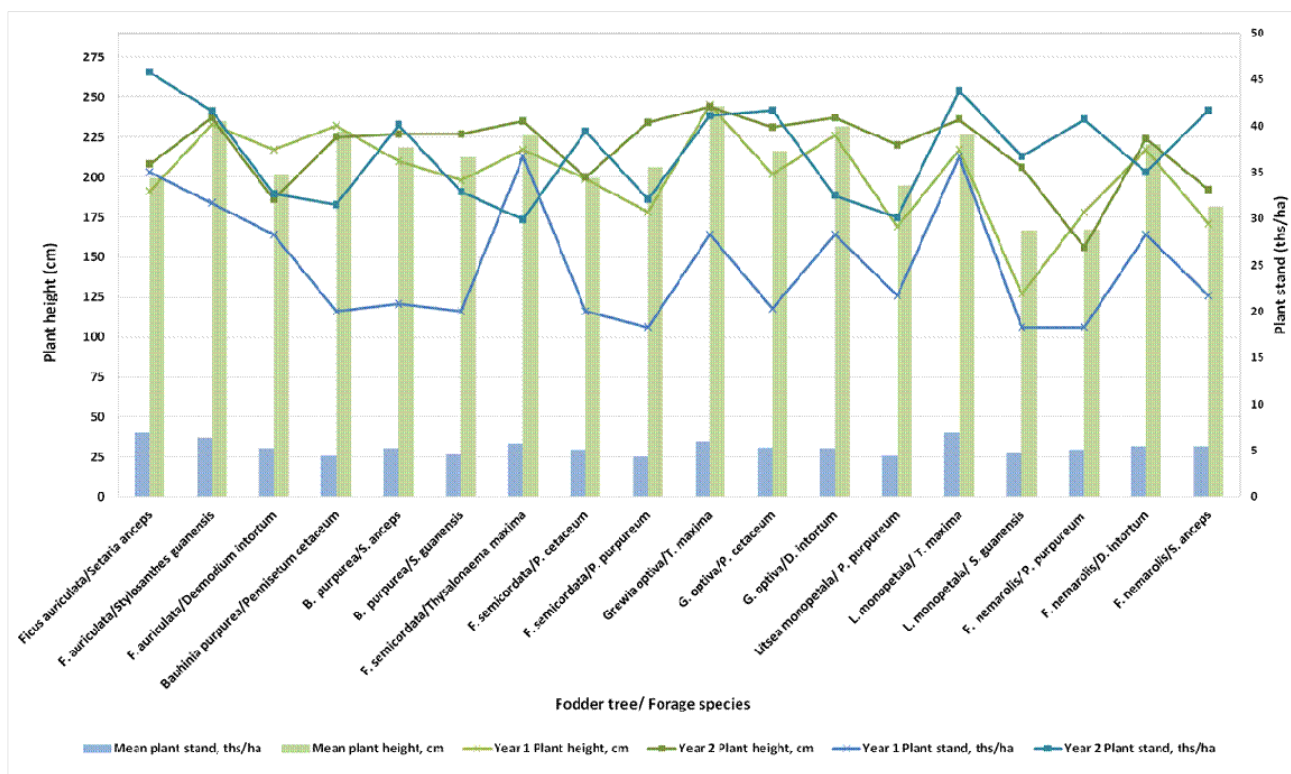


Fig. 1 The first and second year mean plant height (cm) and stand (thousand ths/ha) of maize.

these trees also had higher maize heights and cob numbers as compared to other species. The best combinations for grain yields were *L. monopetala*/*T. maxima* (3,956 kg/ha) followed by *G. optiva*/*T. maxima* (3,451 kg/ha). Regarding the stover yield, *F.*

auriculata, *L. monopetala* and *G. optiva* had significantly higher effects. Most figures/data of that area were higher than average compared to previous years. It was noticeable that weather condition was more favorable in second year for plant growth to

form more grain and stover biomass as there was frequent rain during the crop growing season.

Fig. 1 presents the means of the first and second year growth data on plant height and stand which significantly ($p < 0.05$) and at par differed between the years. Better fodder trees favoring maize growth were *G. optiva* and *F. auriculata*. Better combinations were *G. optiva/T. maxima*, *L. monopetala/T. maxima* and *G. optiva/D. intortum*. These treatments had higher mean plant heights (212-231 cm) and stands (32-35 ths/ha) being at par and non-significant as compared to other species. No data are available to compare more as no similar research is carried out.

Fig. 2 presents the first and second year means of grain and stover yields of maize which were significant at $p < 0.05$. Better fodder trees for producing higher yields were: *G. optiva* (3,063 kg/ha and 3,494 kg/ha) and *F. auriculata* (2,634 kg/ha and 3,907 kg/ha, in the first and second year, respectively). Four combinations: *G. optiva* with *T. maxima* (3,350 kg/ha) that out-yielded the control (3,234 kg/ha), *L. monopetala* with *T. maxima* (3,194 kg/ha), *G. optiva* with *D. intortum* (3,175 kg/ha) and *F. auriculata* with *S. anceps* (3,098 kg/ha) revealed to be better for increased grain yields.

In the third year of experimentation, the growth of fodders was more influencing on standing crop and so observation of maize was done in the upper edge part of the T-riser also. Therefore, plots were laid out in the edge side also from the trees and data recorded.

As presented in Table 6, better combinations of fodder species for higher grain yield in the third year were *G. optiva* and *F. auriculata* which enhanced to produce heavier yields than control. Suitable fodder trees in combinations with forage species for higher stover yields were found (*G. optiva*, *F. auriculata* and *B. purpurea*). The yields were higher in the edge part of terrace than the bottom part. This might be due to more sunlight and better photosynthesis in the terrace edge to form bigger plants and large grains. The grand

means were highly significant ($p < 0.01$) and the grain yield was higher by 408 kg/ha in terrace edge than the riser bottom part of terrace. Similar trend was also found in stover yield which was higher by 397 kg/ha in the terrace edge.

The height and stand means of maize (Table 6) were significant ($p < 0.05$) and at par. Taller plants were grown under *B. purpuria* and *F. auriculata*. Higher ear height was under *F. auriculata* and *G. optiva*. The least height was under *F. nemarolis*. The participant peasants and others in the hills take taller plants positively for fodder and fuel-wood. Similarly, *G. optiva* and *L. monopetala* preserved the highest maize plant stands in comparison to *F. semicordata* which had the least number of stands. Higher numbers of cobs were observed under *G. optiva* and *F. auriculata* whereas the least number was under *F. semicordata*. The stands and cobs in bottom parts were less than edge parts (by 2-4 ths/ha). Maximum difference was under *F. semicordata* (13 ths/ha). On the contrary, plant and ear heights were equal or higher in the bottom part. Number of barren plants was found negligible and so not presented. It was higher under *F. semicordata* and *G. optiva*. Most data suggest the data generated by the station from other locations.

The data on grain and stover yields of maize recorded in the 4th year are presented in Table 7. Overall, *F. auriculata* favored to produce highly significantly ($p < 0.01$) the highest yield of maize grain (3,898 kg/ha) and stover (5,562 kg/ha) followed by *B. purpurea* (3,629 kg/ha and 5,500 kg/ha, respectively). Good weather condition with timely rainfall might be the reason for good growth and higher grain and biomass yields in comparison to past three years.

Regarding the combination of fodder tree and forage species, *F. auriculata/D. intortum* performed best and out-yielded (4,377 kg/ha grain and 7,444 kg/ha stover). *B. purpurea/S. anceps* ranked second (4,008 kg/ha and 5,222 kg/ha) followed by *G.*

optiva/*D. intortum* (3,863 kg/ha and 5,777 kg/ha). The grain yield on average was higher by 331 kg/ha in the edge part of terrace (3,337 kg/ha) than the bottom part (3,006 kg/ha). More sunshine for better photosynthesis

with aeration in the terrace edge might enhance to form large bold grains. On contrary to this, stover yield was higher by 152 kg/ha (4,828 kg/ha) in the bottom part of the plot than the edge part (4,676 kg/ha).

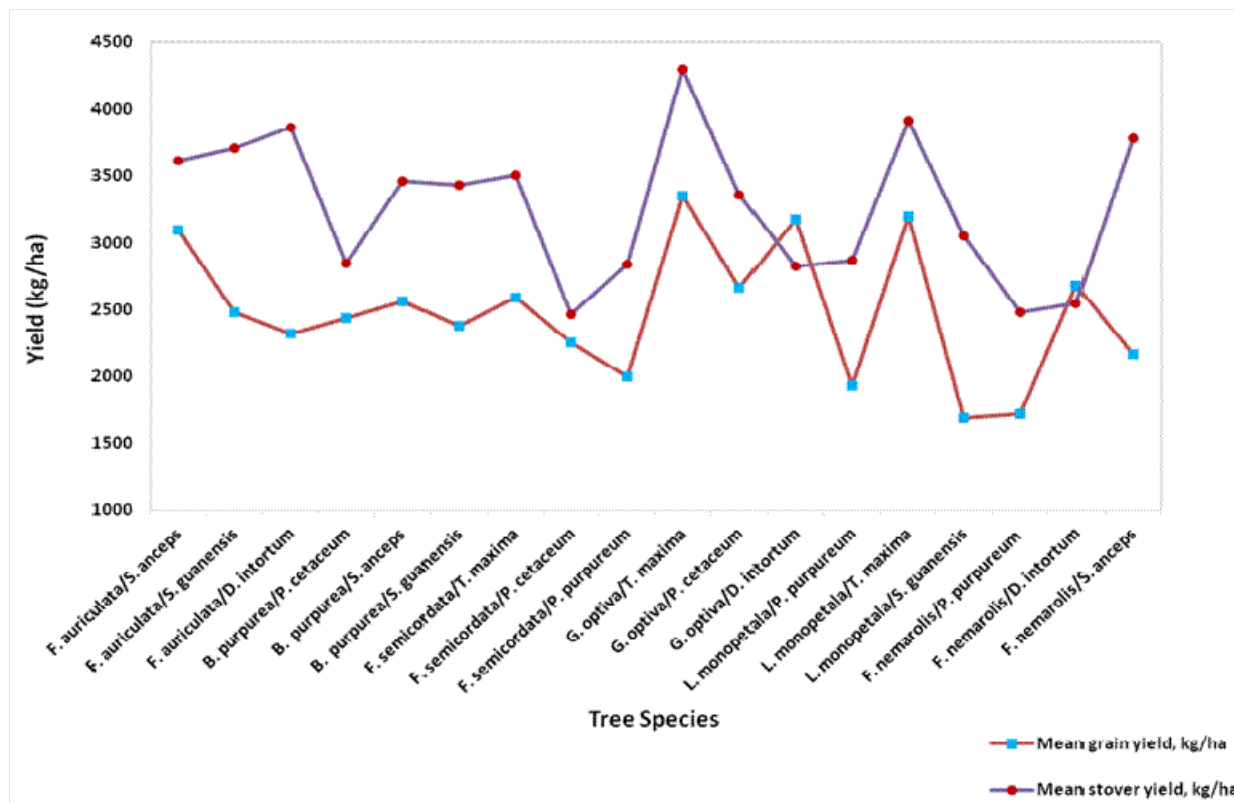


Fig. 2 The first and second year mean grain and stover yields (kg/ha) of maize.

Table 6 Effect of different combinations of riser planted tree and forage species on grain and stover yields of maize (kg/ha) (year 3), Dhankuta district, Patle.

Tree species	Forage species	Grain yield (kg/ha)		Stover yield (kg/ha)		Mean height (cm)		Mean No. (ths/ha)	
		Edge part	Bottom part	Edge part	Bottom part	Plant	Ear	Stand	Cob
Terrace part						Edge/Bott.	Edge/Bott.	Edge/Bott.	Edge/Bott.
<i>F. auriculata</i>	<i>S. anceps</i> + <i>S. guanensis</i> + <i>D. intortum</i>	3,520	2,713	3,722	2,713	184/191	140/101	43.6/36.0	44.8/34.7
<i>B. purpurea</i>	<i>P. cetaceum</i> + <i>S. anceps</i> + <i>S. guanensis</i>	3,161	2,529	3,464	2,529	179/201	95/98	34.8/39.6	37.0/36.4
<i>F. semicordata</i>	<i>T. maxima</i> + <i>P. cetaceum</i> + <i>P. purpureum</i>	2,275	2,009	2,388	2,009	196/177	102/98	29.3/32.0	27.5/33.6
<i>G. optiva</i>	<i>D. intortum</i> + <i>P. cetaceum</i> + <i>T. maxima</i>	3,358	3,108	3,377	3,108	160/185	95/107	43.3/40.9	40.0/38.7
<i>L. monopetalata</i>	<i>S. guanensis</i> + <i>P. purpureum</i> + <i>T. maxima</i>	2,889	2,881	2,785	2,881	165/195	80/107	38.2/42.6	34.9/37.3
<i>F. nemarolis</i>	<i>P. purpureum</i> + <i>D. intortum</i> + <i>S. anceps</i>	2,845	2,357	3,031	2,357	164/161	75/90	44.3/33.8	43.2/25.8
Grand mean		3,008	2,600	3,128	2,731	175/185	98/100	38.9/37.5	37.9/34.4
Control/Open			3,058		3,101	189	99	40.0	39.4

Table 7 Effect of different combinations of riser planted tree and forage species on grain and stover yields of maize (kg/ha) (year 4), Dhankuta district, Patle.

Tree species	Forage species	Grain yield (kg/ha)		Stover yield (kg/ha)	
		Edge part	Bottom part	Edge part	Bottom part
<i>F. auriculata</i>	<i>S. anceps</i> + <i>S. guanensis</i> + <i>D. intortum</i>	3,874	3,922	5,271	5,852
<i>B. purpurea</i>	<i>P. cetaceum</i> + <i>S. anceps</i> + <i>S. guanensis</i>	3,738	3,519	5,370	5,629
<i>F. semicordata</i>	<i>T. maxima</i> + <i>P. cetaceum</i> + <i>P. purpureum</i>	3,245	2,537	4,864	4,203
<i>G. optiva</i>	<i>D. intortum</i> + <i>P. cetaceum</i> + <i>T. maxima</i>	3,546	3,092	5,271	5,259
<i>L. monopetala</i>	<i>S. guanensis</i> + <i>P. purpureum</i> + <i>T. maxima</i>	2,922	2,734	3,845	4,851
<i>F. nemarolis</i>	<i>P. purpureum</i> + <i>D. intortum</i> + <i>S. anceps</i>	2,698	2,233	3,432	3,174
Grand mean		3,337	3,006	4,676	4,828
Control/Open		3,046		3,400	

Table 8 Effects of fodder trees with forages on maize parameters in the 4th year.

Tree/forage combination	Mean height (cm)	Barren plant (ths/ha)	Mean number (ths/ha)
			Stand/cob
<i>F. auriculata</i> / <i>S. anceps</i> + <i>S. guanensis</i> + <i>D. intortum</i>			
Edge part	198/108	0.0	43.7/40.6
Bottom part	216/121	1.1	43.3/38.5
<i>B. purpurea</i> / <i>P. cetaceum</i> + <i>S. anceps</i> + <i>S. guanensis</i>			
Edge part	211/111	0.0	48.1/44.0
Bottom part	208/116	1.4	45.6/42.6
<i>F. semicordata</i> / <i>T. maxima</i> + <i>P. cetaceum</i> + <i>P. purpureum</i>			
Edge part	183/98	1.5	41.5/38.5
Bottom part	214/116	1.2	28.8/26.0
<i>G. optiva</i> / <i>D. intortum</i> + <i>T. maxima</i> + <i>P. cetaceum</i>			
Edge part	199/102	1.8	49.0/46.4
Bottom part	221/118	0.9	45.9/39.8
<i>L. monopetala</i> / <i>S. guanensis</i> + <i>P. purpureum</i> + <i>T. maxima</i>			
Edge part	188/102	0.7	38.3/35.4
Bottom part	184/117	0.0	40.0/33.1
<i>F. nemarolis</i> / <i>P. purpureum</i> + <i>D. intortum</i> + <i>S. anceps</i>			
Edge part	177/87	0.5	40.0/34.8
Bottom part	177/94	1.0	38.3/33.4
Control/Open	187/102	1.1	30.1/37.1

The growth parameters of maize monitored in the 4th year (Table 8) varied significantly and non-significantly. The highest plant height (210 cm) was recorded under *G. optiva* and *B. purpurea* combinations, the least (177 cm) being under *F. nemarolis*. Ear height also followed the same trend. *G. optiva* and *F. auriculata* combination was found better to retain higher plant stands (47.5 ths/ha and 43.5 ths/ha) and cobs in the experiment, whereas the least number (35.1 ths/ha) was counted under *F. semicordata*. Plant stands were slightly higher (by 3-4

ths/ha) than cob number. Productive cob number significantly varied from 32.3 ths/ha (*F. semicordata*) to 43.3 ths/ha (*B. purpurea* and *G. optiva*). No research was done elsewhere on fodder trees and forages in the risers and the adjacent crops in bottom and edge part of terrace to compare the data. So the results are new to the scientific community world-wide.

In general, the stands and cobs in bottom parts were less than edge parts (by 2-4 ths/ha). Maximum difference was under *F. semicordata* (13 ths/ha). On the opposite, plant and ear heights were equal or higher in the

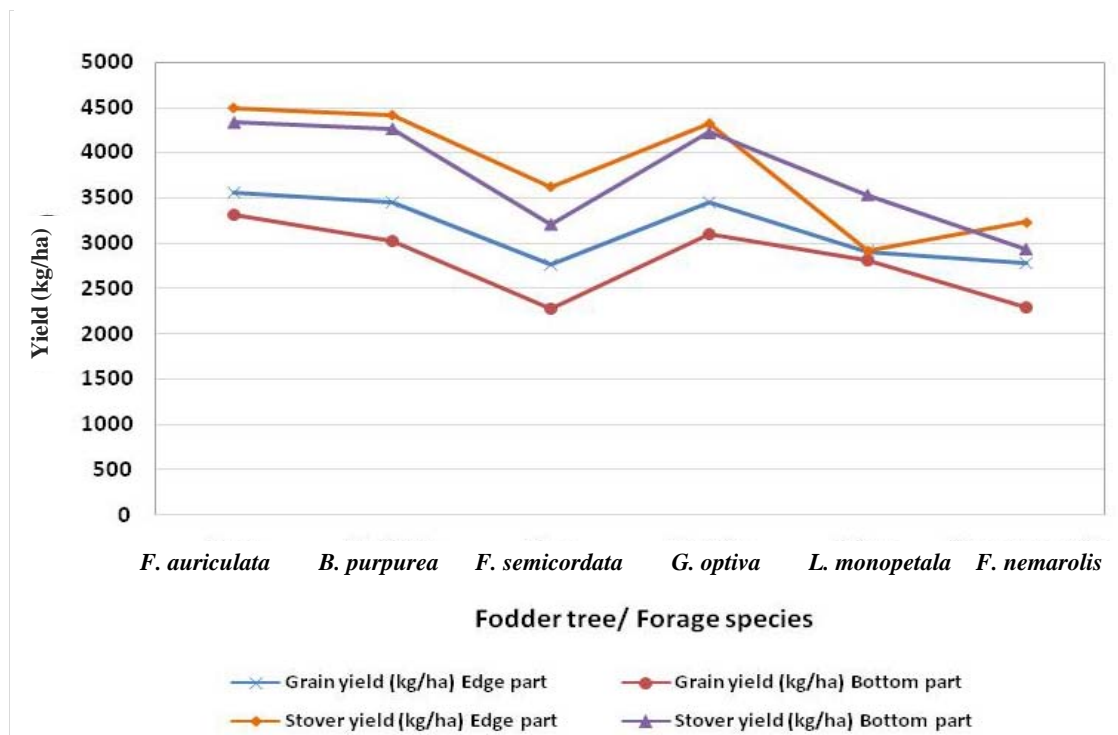


Fig. 3 The third and fourth year mean grain and stover yields (kg/ha) of maize from edge of terrace and bottom of riser. The combination of forage species under tree species are as: *F. auriculata* (*S. anceps*, *S. guanensis*, *D. intortum*); *B. purpurea* (*P. cetaceum*, *S. anceps*, *S. guanensis*); *F. semicordata* (*T. maxima*, *P. cetaceum*, *P. purpureum*); *G. optiva* (*T. maxima*, *P. cetaceum*, *D. intortum*); *L. monopetala* (*P. purpureum*, *T. maxima*, *S. guanensis*); *F. nemarolis* (*P. purpureum*, *D. intortum*, *S. anceps*).

Table 9 Mean effect (year 3 & 4) of different combinations of tree and forage species on grain and stover yields of maize (kg/ha), mid hill of Dhankuta district, Patle.

Tree species	Forage species	Grain yield (kg/ha)		Stover yield (kg/ha)	
		Edge part	Bottom part	Edge part	Bottom part
Terrace part					
<i>F. auriculata</i>	<i>S. anceps</i> + <i>S. guanensis</i> + <i>D. intortum</i>	3,562	3,317	4,496	4,332
<i>B. purpurea</i>	<i>P. cetaceum</i> + <i>S. anceps</i> + <i>S. guanensis</i>	3,451	3,024	4,417	4,261
<i>F. semicordata</i>	<i>T. maxima</i> + <i>P. cetaceum</i> + <i>P. purpureum</i>	2,760	2,273	3,626	3,204
<i>G. optiva</i>	<i>D. intortum</i> + <i>P. cetaceum</i> + <i>T. maxima</i>	3,452	3,100	4,324	4,218
<i>L. monopetala</i>	<i>S. guanensis</i> + <i>P. purpureum</i> + <i>T. maxima</i>	2,906	2,808	2,915	3,531
<i>F. nemarolis</i>	<i>P. purpureum</i> + <i>D. intortum</i> + <i>S. anceps</i>	2,772	2,290	3,231	2,931
Grand mean		3,151	2,802	3,835	3,746
Control/Open		3,052		3,250	

bottom part. Number of barren plants (not presented) was found to be negligible however that was higher under *F. semicordata* and *G. optiva*.

The means of the third and fourth years' maize data significantly differed between the years and treatments and were at par (Fig. 3 and Table 9). The results suggest that the best fodder tree combination favoring grain and stover yield production of maize was *F. auriculata* (3,440 kg/ha and 4,414 kg/ha) followed by

G. optiva (3,276 kg/ha and 4,104 kg/ha) and *B. purpurea* (3,240 kg/ha and 4,339 kg/ha). Grain and stover yields were higher in the edge parts than bottom parts of the terrace under all fodder trees combinations with forage crops. It might be due to more sunlight and air flow in the edges of terraces than the riser bottom parts. According to the grand means, grain yield was higher by 349 kg/ha and stover yield was by 89 kg/ha in the terrace edge than the

terrace bottom in the experiment. Grain yield was at par and stover yield was significantly ($p < 0.05$) higher than control (open part). However, it was reported that maize yield was not substantially affected with tree age due to shading effects [17].

3.4 Millet Crop Observation Data

The first year data of fodder trees/forages and finger millet interaction are presented in Table 10. The highest grain yield (2,000 kg/ha) of millet was under *G. optiva*/*P. cetaceum* followed by *F. auriculata*/*S. guanensis* (1,833 kg/ha). *F. semicordata*/*P. cetaceum* severely affected millet yield (916 kg/ha). Better combinations were of *L. monopetala* and *F. auriculata*. The data were significant at $p < 0.05$ level. Millet straw yields (8.8 t/ha to 13.8 t/ha) were also significant and at par. Straw was produced over 14 t/ha in the combinations of *B. purpurea*/*S. guanensis*, *F. auriculata*/*S. anceps* and *F. auriculata*/*D. intortum*. *F. nemarolis* suppressed the plant. Overall *L.*

monopetala favored more grain (1,611 kg/ha) followed by *G. optiva* and *F. auriculata* (1,542 kg/ha). Plant height ranging 67-93 cm in the treatments gave non-significant results, the highest was under *L. monopetala*. The major diseases of millet in that area were scored. As shown (Table 10), neck blast was 1%-2% and finger blast was 4%-9%, means (5%-7%).

Combined effects of fodder trees with forages on millet are shown in Table 11 for the second year. Four combinations were found acceptable (1,708-1,766 kg/ha) except *F. semicordata* and *G. optiva*. These combinations were found superior to others in straw yield, plant stand and head numbers as well. There was significant gap between edge and bottom parts of terrace. The means showed that grain yield, head number and plant heights were higher in the edge part of all treatments, whereas plant stand and straw yield were higher in the bottom part of terrace. Higher grain yield by 234 kg/ha in edge part might be verified by the better environment to form large finger heads.

Table 10 Effect of different combinations of tree and forage species on yield and other agronomic traits of finger millet (year 1), Dhankuta, Patle.

Treatment combination	Grain yield (kg/ha)	Straw yield with husk (t/ha)	Plant height (cm)	Disease (%)	
				Neck blast	Finger blast
<i>F. auriculata</i> / <i>S. anceps</i>	1,625	14.08	73	2	6
<i>F. auriculata</i> / <i>S. guanensis</i>	1,833	11.67	72	1	8
<i>F. auriculata</i> / <i>D. intortum</i>	1,166	13.83	82	2	6
Mean	1,541	13.19	75.7	1.7	6.7
<i>B. purpurea</i> / <i>P. cetaceum</i>	1,458	13.33	88	1	5
<i>B. purpurea</i> / <i>S. anceps</i>	1,624	13.50	73	2	6
<i>B. purpurea</i> / <i>S. guanensis</i>	1,083	14.66	72	2	6
Mean	1,388	13.83	77.7	1.7	5.7
<i>F. semicordata</i> / <i>T. maxima</i>	1,083	11.33	93	1	4
<i>F. semicordata</i> / <i>P. cetaceum</i>	1,408	8.17	67	2	6
<i>F. semicordata</i> / <i>P. purpureum</i>	916	10.66	70	2	8
Mean	1,136	10.05	76.7	1.7	6.0
<i>G. optiva</i> / <i>T. maxima</i>	1,408	12.42	79	1	7
<i>G. optiva</i> / <i>P. cetaceum</i>	2,000	12.48	71	1	7
<i>G. optiva</i> / <i>D. intortum</i>	1,233	10.67	69	1	8
Mean	1,547	11.86	73.0	1.0	7.3
<i>L. monopetala</i> / <i>P. purpureum</i>	2,000	13.00	90	2	9
<i>L. monopetala</i> / <i>T. maxima</i>	1,499	11.46	78	2	9
<i>L. monopetala</i> / <i>S. guanensis</i>	1,333	12.17	68	2	4
Mean	1,611	12.21	78.7	2.0	7.3
<i>F. nemarolis</i> / <i>P. purpureum</i>	1,324	8.07	72	1	4
<i>F. nemarolis</i> / <i>D. intortum</i>	1,583	11.00	77	1	8
<i>F. nemarolis</i> / <i>S. anceps</i>	1,500	7.33	79	1	4
Mean	1,469	8.80	76.0	1.0	5.3

Table 11 Effect of fodder trees with forage species on yield and other parameters of finger millet (year 2), Dhankuta, Patle.

Tree/forage combination	Terrace part	Grain yield (kg/ha)	Straw yield (kg/ha)	Plant stand (100 ths/ha)	Plant height (cm)	Head No. (100 ths/ha)
<i>F. auriculata</i> / <i>S. anceps</i> + <i>S. guanensis</i> + <i>D. intortum</i>	Edge	2,037	8,081	15.6	83	12.8
	Bottom	1,708	8,462	16.8	74	13.2
<i>B. purpurea</i> / <i>P. cetaceum</i> + <i>S. anceps</i> + <i>S. guanensis</i>	Edge	2,035	6,794	15.8	78	12.7
	Bottom	1,714	7,567	16.1	69	12.1
<i>F. semicordata</i> / <i>T. maxima</i> + <i>P. cetaceum</i> + <i>P. purpureum</i>	Edge	1,700	7,717	12.9	78	10.1
	Bottom	1,238	5,890	14.9	71	10.4
<i>G. optiva</i> / <i>D. intortum</i> + <i>T. maxima</i> + <i>P. cetaceum</i>	Edge	1,423	6,470	12.9	76	9.7
	Bottom	1,566	6,903	17.9	74	13.3
<i>L. monoptala</i> / <i>S. guanensis</i> + <i>P. purpureum</i> + <i>T. maxima</i>	Edge	1,667	6,084	15.3	77	9.7
	Bottom	1,718	7,567	14.4	70	9.7
<i>F. nemarolis</i> / <i>P. purpureum</i> + <i>D. intortum</i> + <i>S. anceps</i>	Edge	2,258	7,536	17.3	80	12.5
	Bottom	1,766	6,890	15.5	84	12.4
Edge part mean		1,852	7,114	14.97	78.7	12.8
Bottom part mean		1,618	7,213	15.93	73.7	11.8

Table 12 compiles results of finger millet as affected by fodder trees with forages for the fourth year. Significantly highest grain yields were harvested under *F. nemarolis* (2,124/1,860 kg/ha) and *B. purpurea* (1,907/1,844 kg/ha). These combinations were found superior to others in straw yield (10.52/8.61 t/ha and 9.75/8.08 t/ha, respectively) and plant height, too. There was significant gap between edge and bottom parts of terrace. The grand means showed that grain yield was higher in edge part by 264 kg/ha and straw yield by 1.91 t/ha. Plant heights were also higher in the edge part of terrace. Higher yields in edge part might be verified by the better environment to form heavy finger heads. The treatment means were significant at 5% level.

The mean results of the third and fourth years as combined effects of fodder trees with forages on millet are presented in Table 13. ANOVA of grain yields gave significant ($p < 0.05$) results, while straw yields were not significant between the treatments. The best combinations for grain yields (1,860-1,844 kg/ha) and for straw yields (8.08-8.62 t/ha) were *F. nemarolis* and *B. purpurea*. *F. nemarolis* enhanced increased productive heads numbers. However, there was no consistency trend in head number and plant heights in the treatments and data were also non-significant. Finger-millet

yield was decreased with tree age due to shading effects [17]. Similarly, as reported by Osman *et al.* [19] cowpea sole crops had significant grain yield losses of up to 21% under trees compared to outside, and pearl millet yield was reduced up to 67%. Intercropping of cowpea and millet gave significantly higher economic benefit.

The two years mean data presented in Table 14 showed that fodder trees had marked effect on finger millet maturity. Maturity was observed during the middle phase of finger maturity. Finger millet was relayed after maize, transplanted in summer (August) and maturity occurred in winter (November). *F. semicordata* followed by *G. optiva* significantly delayed the maturity as compared to other trees. There was the highest maturity (70%) under *F. auriculata* and *F. nemoralis* which had smaller trees due to slow growth behavior. Cowpea (*Vigna unguiculata*) and pearl millet (*P. glaucum*) sole and intercrops were grown under and outside the shade of *Parkia biglobosa* trees. Flowering was earlier outside than under the trees and intercrops flowered earlier than sole crops [19, 20]. Matured (6-8 m tall) *B. purpurea* and *A. jullibrissin* affect decreased growth and yield parameters of maize and millet up to 5-6 m. The closer the crops are grown to the trees, the severe the effect on the growth and yield of crops [20].

Table 12 Effect of different combinations of tree and forage species on yield and other agronomic traits of finger millet (year 4), Dhankuta, Patle.

Treatment combination	Grain yield (kg/ha)	Straw yield with husk (t/ha)	Plant height (cm)
On terrace	Edge/Bottom	Edge/Bottom	Edge/Bottom
<i>F. auriculata/S. anceps</i>	1,988/2,244	10.71/11.73	86/87
<i>F. auriculata/S. guanensis</i>	1,366/1,324	5.44/ 6.48	83/77
<i>F. auriculata/D. intortum</i>	1,566/1,146	6.67/7.64	77/88
Mean	1,640/1,571	7.61/8.62	82/84
<i>B. purpurea/P. cetaceum</i>	1,077/1,666	7.22/7.56	86/74
<i>B. purpurea/S. anceps</i>	2,533/1,866	13.93/7.38	94/85
<i>B. purpurea/S. guanensis</i>	2,111/2,000	8.11/9.31	77/71
Mean	1,907/1,844	9.75/8.08	86/77
<i>F. semicordata/T. maxima</i>	1,055/874	6.07/4.73	92/80
<i>F. semicordata/P. cetaceum</i>	1,948/1,235	12.33/10.18	85/85
<i>F. semicordata/P. purpureum</i>	968/1,333	5.67/6.58	73/64
Mean	1,324/1,147	8.02/7.16	83/76
<i>G. optiva/T. maxima</i>	1,666/1,733	7.16/7.47	88/97
<i>G. optiva/P. cetaceum</i>	2,288/1,502	9.20/5.77	65/75
<i>G. optiva/D. intortum</i>	1,473/1,324	7.27/8.16	79/78
Mean	1,809/1,520	7.88/7.13	77/83
<i>L. monopetala/P. purpureum</i>	1,911/985	7.70/5.48	70/75
<i>L. monopetala/T. maxima</i>	1,111/1,811	5.87/7.16	89/80
<i>L. monopetala/S. guanensis</i>	1,322/760	6.67/5.38	81/71
Mean	1,448/1,185	6.75/6.01	80/75
<i>F. namarolis/P. purpureum</i>	1,473/1,722	6.51/8.63	91/74
<i>F. namarolis/D. intortum</i>	2,677/2,053	12.88/9.10	91/85
<i>F. namarolis/S. anceps</i>	2,222/1,804	12.16/8.09	92/82
Mean	2,124/1,860	10.52/8.61	91/80

Table 13 Effect of combinations of tree and forage species on yield and other agronomic traits of finger millet (means of years 3 and 4), Dhankuta, Patle.

Treatment combination	Grain yield (kg/ha)	Straw yield (t/ha)	Productive head (100 ths/ha)	Plant height (cm)
On terrace	Edge part/Bottom part	Edge part/Bottom part	Edge part/Bottom part	Edge part/Bottom part
<i>F. auriculata/S. anceps</i>	1,647/1,638	10.71/11.7	9.0/7.0	75/85
<i>F. auriculata/S. guanensis</i>	1,408/1,160	4.44/6.48	8.0/9.5	88/79
<i>F. auriculata/D. intortum</i>	1,393/1,171	6.67/7.64	8.5/12.0	87/92
Mean	1,483/1,323	7.27/8.60	8.5/9.5	83/85
<i>B. purpurea/P. cetaceum</i>	1,102/1,221	7.22/7.56	10.5/7.0	88/74
<i>B. purpurea/S. anceps</i>	2,116/1,433	14.93/7.38	9.0/7.5	87/76
<i>B. purpurea/S. guanensis</i>	1,404/1,335	8.11/9.31	7.5/6.5	74/75
Mean	1,541/1,330	10.08/8.08	9.0/7.0	83/75
<i>F. semicordata/T. maxima</i>	883/720	6.07/3.73	7.0/6.5	87/80
<i>F. semicordata/P. cetaceum</i>	1,577/1,034	13.33/10.2	7.5/10.0	80/77
<i>F. semicordata/P. purpureum</i>	884/958	5.67/6.58	13.0/11.0	84/71
Mean	1,115/904	8.36/3.78	9.17/9.2	84/76
<i>G. optiva/T. maxima</i>	1,435/1,398	7.16/7.47	9.0/9.5	83/93
<i>G. optiva/P. cetaceum</i>	1,452/1,083	9.20/5.77	7.0/10.0	76/81
<i>G. optiva/D. intortum</i>	1,112/987	7.27/8.16	7.7/7.5	74/80
Mean	1,333/1,156	7.88/7.13	7.7/9.0	78/85

(Table 13 to be continued)

Treatment combination	Grain yield (kg/ha)	Straw yield (t/ha)	Productive head (100 ths/ha)	Plant height (cm)
On terrace	Edge part/Bottom part	Edge part/Bottom part	Edge part/Bottom part	Edge part/Bottom part
<i>L. monopetala/P. purpureum</i>	1,156/844	7.70/5.48	8.0/7.0	64/75
<i>L. monopetala/T. maxima</i>	916/1,255	3.87/7.16	9.0/10.0	84/77
<i>L. monopetala/S. guanensis</i>	874/680	6.67/3.38	7.0/7.5	82/72
Mean	982/926	6.08/5.34	8.0/8.2	77/75
<i>F. nemarolis/P. purpureum</i>	1,037/1,196	5.51/8.63	10.5/8.0	80/77
<i>F. nemarolis/D. intortum</i>	1,680/1,362	12.88/9.10	12.5/11.0	84/75
<i>F. nemarolis/S. anceps</i>	1,861/1,558	12.16/8.09	13.0/8.5	81/80
Mean	1,526/1,372	10.18/8.61	12.0/9.2	82/77

Table 14 Maturity of finger millet as affected by fodder trees with forage combinations.

Fodder trees combined with forage species as above	Terrace edge part		Terrace bottom part		Mean (%)
	> 50% maturity (%)	Total maturity (%)	> 50% maturity (%)	Total maturity (%)	
<i>F. auriculata</i>	37	74	28	67	70
<i>B. purpurea</i>	25	75	21	57	66
<i>F. semicordata</i>	19	39	18	36	38
<i>G. optiva</i>	27	52	22	38	45
<i>L. monopetala</i>	23	55	16	51	53
<i>F. nemoralis</i>	24	78	29	62	70
Control, mean	49		65		57

Table 15 Soil condition of the Terrace riser before planting, first year.

Fodder/forage	N (%)	P (ppm)	K (ppm)	Organic matter (OM) (%)	pH	Texture class
<i>F. semicordata/P. cetaceum</i>	0.08	32.68	75.08	0.45	5.17	LS
<i>F. nemarolis/D. intortum</i>	0.11	30.86	65.80	0.68	4.82	SL
<i>B. purpurea/S. anceps</i>	0.15	23.15	67.83	0.70	4.93	SL
<i>G. optiva/T. maxima</i>	0.08	24.86	62.71	0.77	4.82	SCL
<i>F. auriculata/S. guanensis</i>	0.08	24.29	61.40	0.81	5.07	SCL
<i>L. monopetala/P. purpureum</i>	0.10	24.75	52.72	0.69	5.05	SL
Local grass	0.02	35.09	65.18	0.79	4.88	LS

LS = loamy sand, SL = sandy loam, SCL = sandy clay loam.

4. Soil Analysis Result of the Experiment

Soil samples from T-risers of the experimental plots were taken before research plots establishment and after three years of experiment conduction. The analysis was done in the station lab on nitrogen (N), phosphorus (P), potassium (K), organic matter (OM), soil pH and textural class (Tables 15 and 16). The results showed slight change in the nutrient elements content after three years of experiment (Table 16). OM was significantly increased in all treatments. Overall there was positive indication of the riser planting of fodders.

5. Farmers' Reaction/Comments

All visiting farmers, agriculture and forestry

stakeholders responded positively to the T-riser farming of fodders to be multi-beneficial practice (technology). They requested to provide fodder saplings for cultivation in larger areas and disseminate the riser farming technique in other districts.

5.1 Farmers' Preferences of Tree Fodder

The hill farmers gave following preferences and criteria of tree fodders: Palatable, more fodder production, nutritious for milk and meat production, able to harvest 2-3 times a year to supply green fodder during lean period (Nov.-May). They also expect from the trees supporting fuel-wood from twigs, having less effect on maize and other crops.

Table 16 Soil condition of the Terrace riser after three years.

Fodder/forage	N (%)	P (ppm)	K (ppm)	OM (%)	pH	Texture class
<i>F. semicordata/P. cetaceum</i>	0.08	14.78	75.78	1.45	4.58	LS
<i>F. nemarolis/D. intortum</i>	0.08	14.66	54.76	1.26	4.42	LS
<i>B. purpurea/S. anceps</i>	0.07	13.07	63.10	1.10	4.47	LS
<i>G. optiva/T. maxima</i>	0.09	20.03	64.83	1.44	4.37	SL
<i>F. auriculata/S. guianensis</i>	0.06	15.18	58.50	1.39	4.40	SL/LS
<i>L. monopetala/P. purpureum</i>	0.12	24.72	86.00	1.11	4.64	LS
<i>F. semicordata/P. cetaceum</i>	0.06	42.07	122.67	1.18	4.84	LS
Local grass	0.15	10.00	28.67	0.86	4.68	SL

LS = loamy sand, SL = sandy loam.

5.2 Farmers' Preference for Ground Forages

The farmers liked and preferred ground forages species *S. anceps* (Setaria), *P. cetaceum* (Dhus), *P. purpureum* (Napier), *T. maxima* (Amriso) and *D. intortum* (Desmodium) for the following reasons: fast growing, high yielding, livestock preference, milk increment, year round growth, green fodder supply during dry period and cash from broom.

6. Conclusions and Recommendation

(1) In the T-risers of hills and mountains (1,400 m amsl), improved fodder species can be grown successfully. Survival, growth and yields of *P. purpureum*, *P. cetaceum*, *T. maxima*, *S. anceps*, *D. intortum*, *S. guianensis*, are encouraging. Tree species *F. semicordata*, *G. optiva* and *L. monopetala* grow well and give rise to more coppices. These fodder species are fast growing and high yielding in the T-riser.

(2) Closely planted (1.5 m) fodder trees felled at breast height for coppicing have minimal effect on maize and millet crops.

(3) Combination of tree and ground fodder species is good and excellent in the T-riser as most of them are found to be compatible to plant together. The better combinations having minimum effect on maize and millet are *G. optiva*, *F. auriculata*, *B. purpurea*, *F. semicordata* trees with the grown forage species.

(4) For finger millet growth and yield, *F. nemarolis*, *F. auriculata* and *G. optiva* are better.

(5) *G. optiva* and *B. purpurea* have positive effect on maize compared to control, whereas *F. semicordata*, *F. nemarolis* and *L. monopetala* have little negative effect.

(6) Most ground fodders grow vigorously and give high yield (2-3 harvest/year), and could be fed round the year. *P. purpureum*, *T. maxima* and *P. cetaceum* have some negative effect on crops.

(7) The new T-riser farming technology of fodders should be scaled-up throughout hilly region of similar eco-zonal condition as it may result in green and white revolution together.

(8) Agroforestry system in general, and this innovative model, in particular, should get priority from the government and international/non-governmental organizations (I/NGOs), and need to be promoted by concerned agencies.

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Appendix: A few figures highlighting the experimental plot.



Fig. 1 Measuring coppices of *Ficus semicordata* and vigorous Napier in T-riser.



Fig. 2 Vigorously growing *Desmodium intortum* & *Pennisetum cetaceum* in T-riser & maize/millet.



Fig. 3 *Litsea monopetala* with *P. purpureum* and other forages and maize in T-riser.



Fig. 4 *F. semicordata*, *Grewia optiva* (lower T-riser) and other tree forages.



Fig. 5 Finger millet grown under multi-story of vigorously growing *G. optiva* and *Thysalonaema maxima* in T-riser.



Fig. 6 Layout view of experimental plot after clearing weeds in the T-riser.